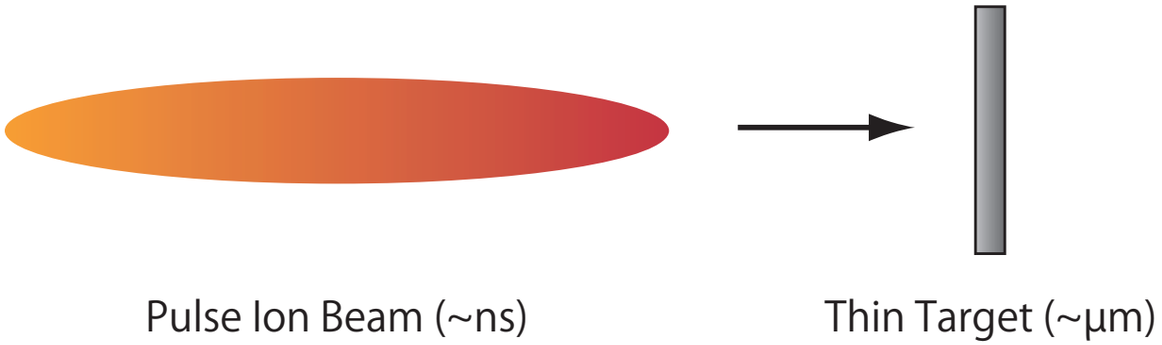
Electro-magnetically driven shock and dissociated hydrogen target for stopping power measurement

K. Kondo[1] T. Moriyama[1]
J. Hasegawa[2] K. Horioka[2] Y. Oguri[1]

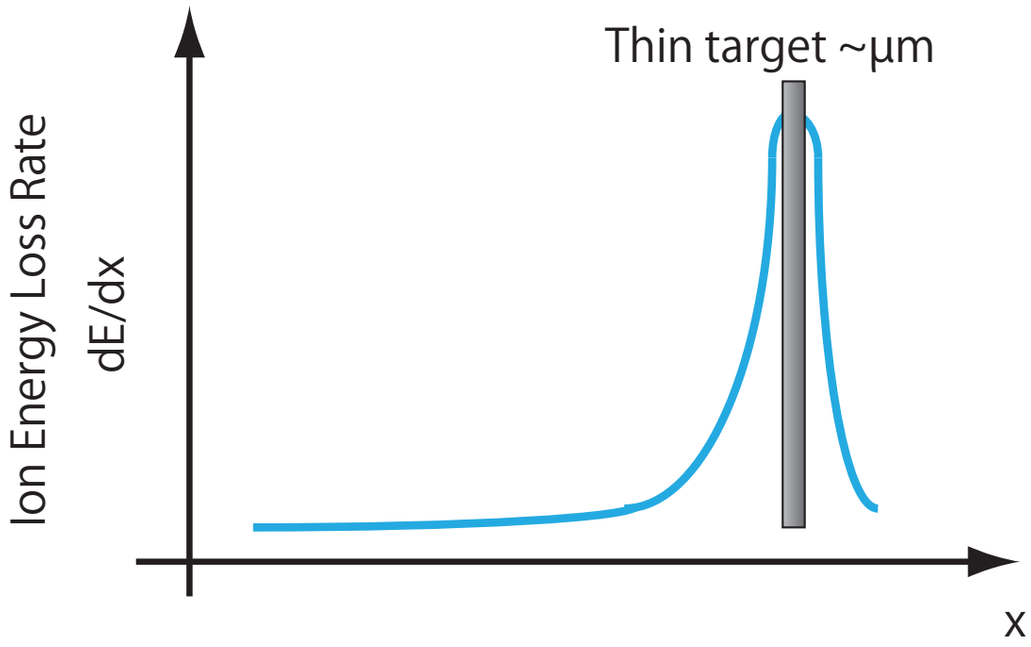
[1] Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology
[2] Department of Energy Sciences, Tokyo Institute of Technology

19th international Symposium on Heavy Ion Inertial FUsion (HIF2012) August 12-17, 2012 Berkeley, California, USA

STOPPING POWER FOR WDM AND HIF SCIENCES



Pulse ion beam deposits the energy to a thin target for WDM.



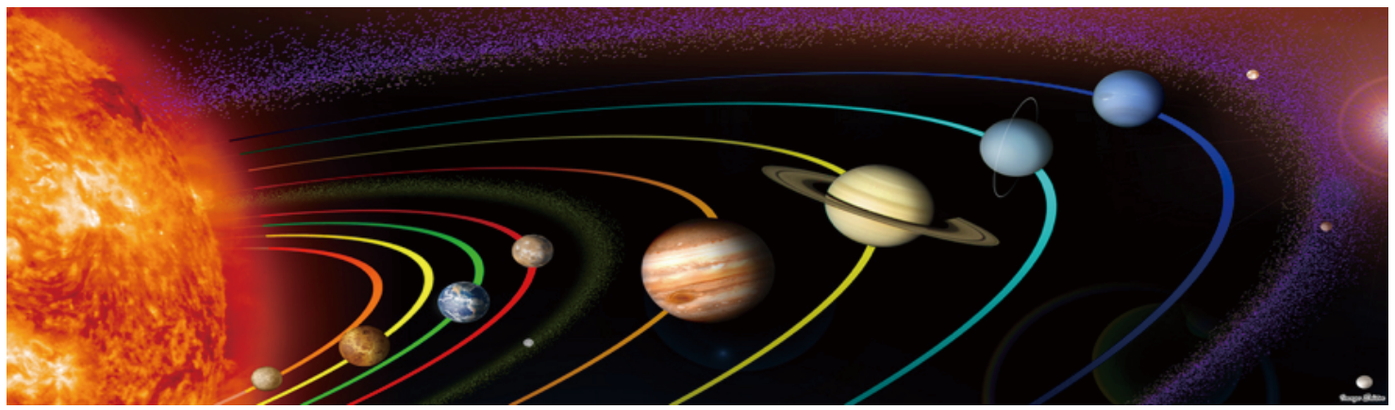
Maximum energy deposition and uniform heating at Bragg peak require short pulses (~ ns) to minimize the hydro motion (~ μm)*.

From solid to WDM and/or high energy density condition, there are the change of chemical state and the phase transition. The stopping power can be changed due to these effects. Precise information is a key to know WDM and/or high energy density condition.

* L. R. Grisham, Phyics of Plasmas, 11, 5727 (2004).

Warm Dense Matter and High Energy Density Sciences

WDM is a state of matter between plasma and condensed matter.
The physical parameters are high density (0.01 to 1 solid density) and low temperature (0.1 to 10 eV).



The total mass and the mass of a core of heavy elements, which are sensitive to EOS of hydrogen, is significant to the planet formation process.

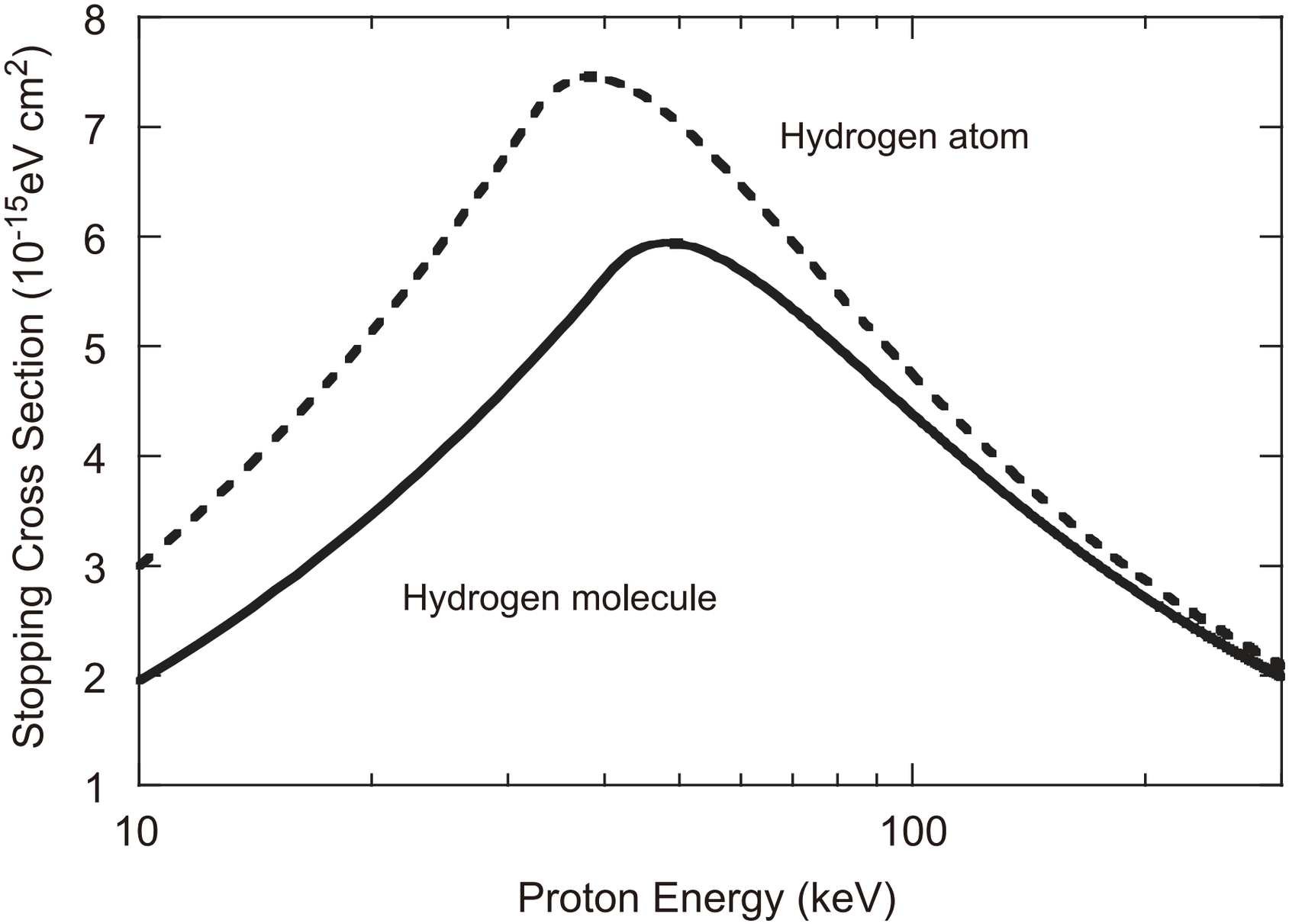
WDM is many body and disorder system.

- Partial electron degeneracy
- Strong ion-ion correlation

Warm Dense Matter is extremely beyond the ideal condition.

19th international Symposium on Heavy Ion Inertial FUsion (HIF2012) August 12-17, 2012 Berkeley, California, USA

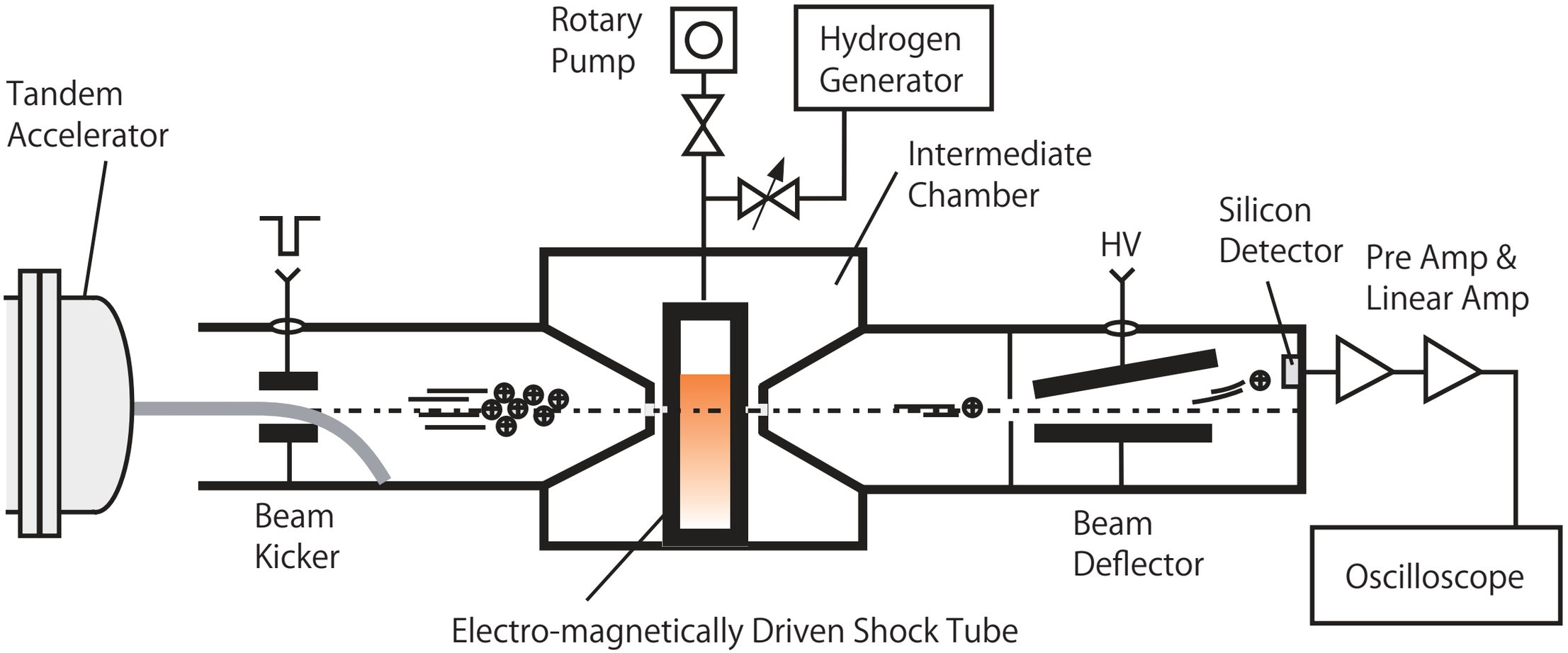
Difference of Stopping Power due to Dissociation



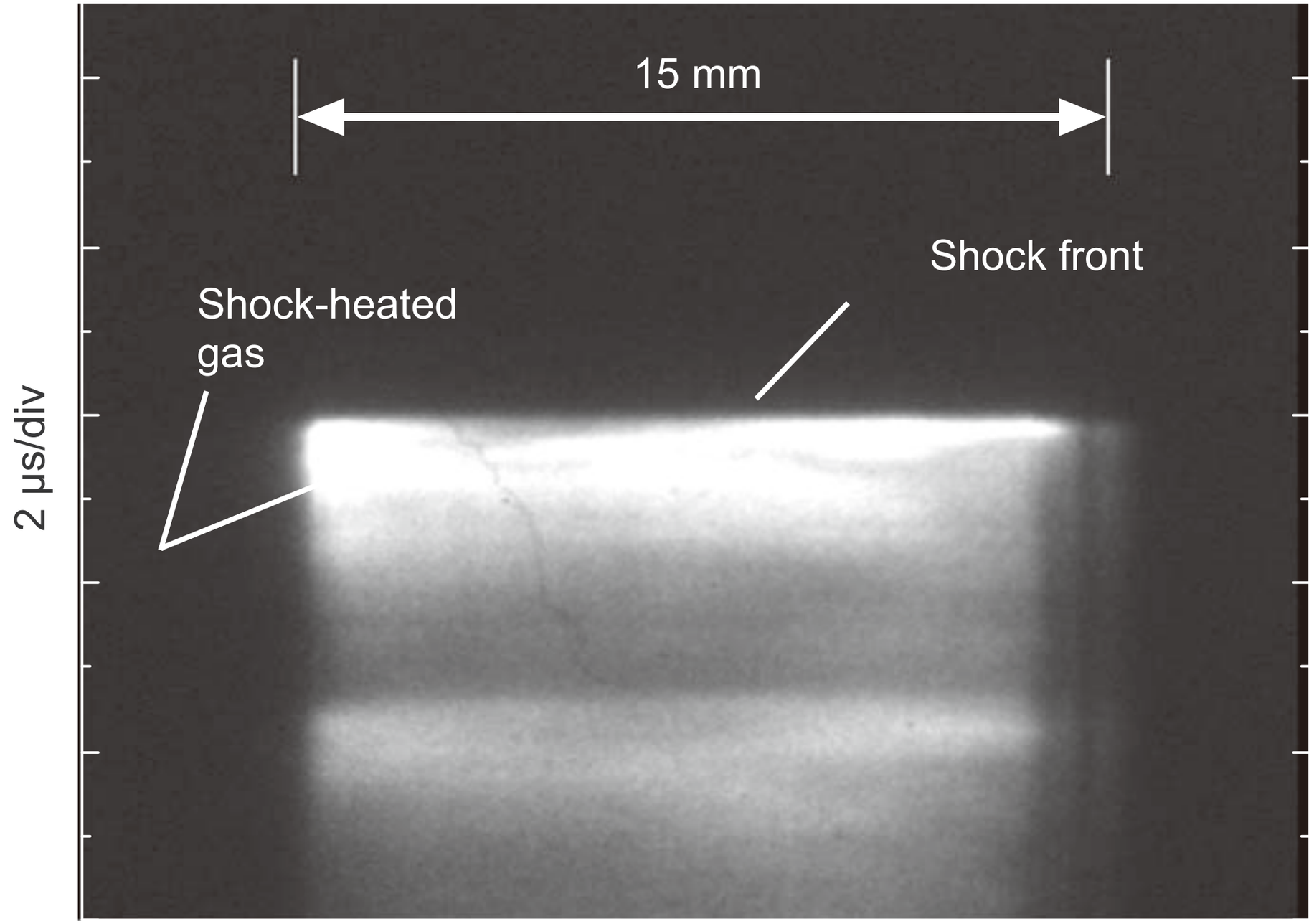
Stopping cross section between molecule and atom for protons*

*J. Hasegawa, et. al., Nucl. Instr. and Meth. A 606 205 (2009)

Previous Experimental Setup



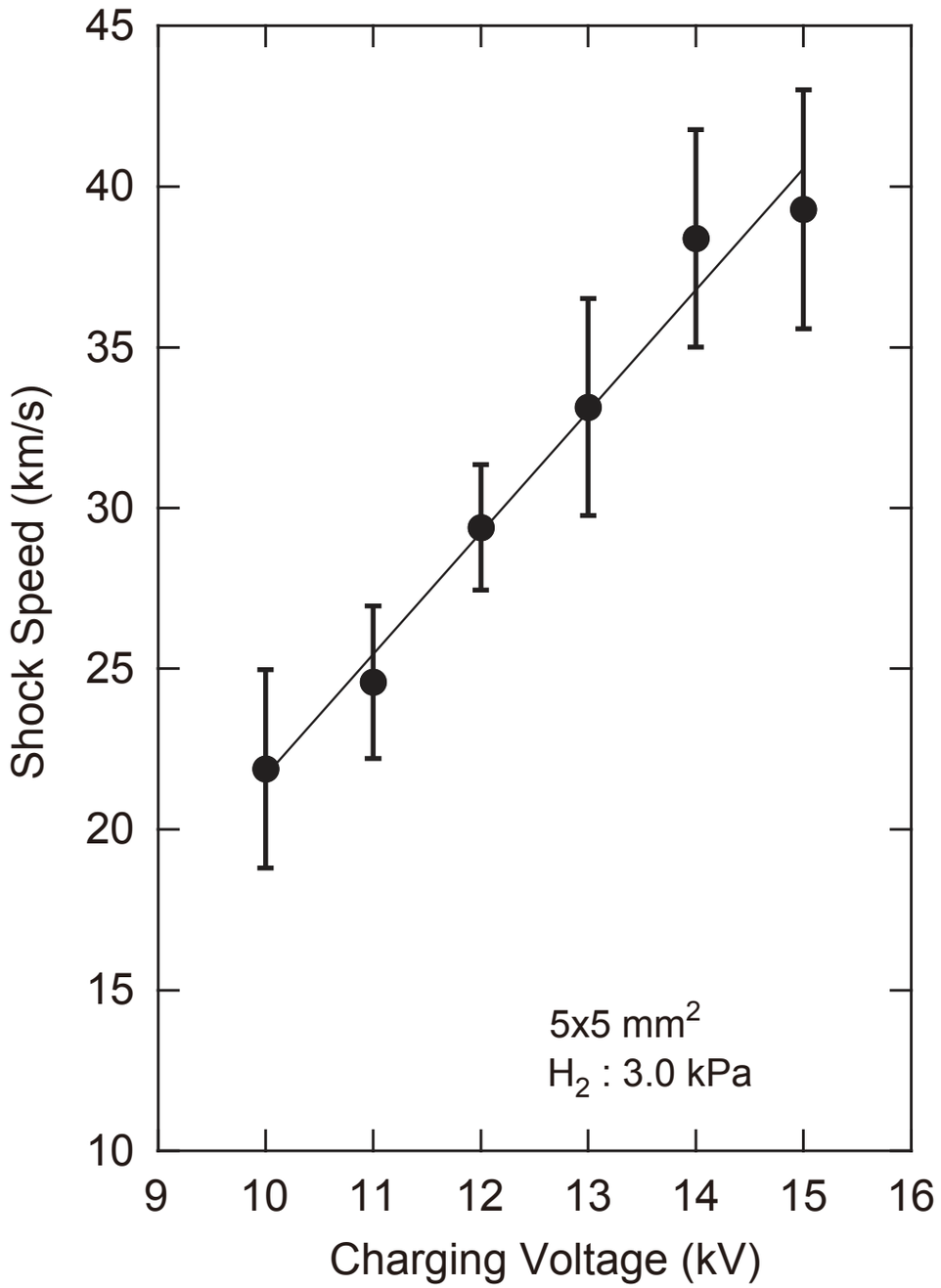
Shock Wave and Gas Target



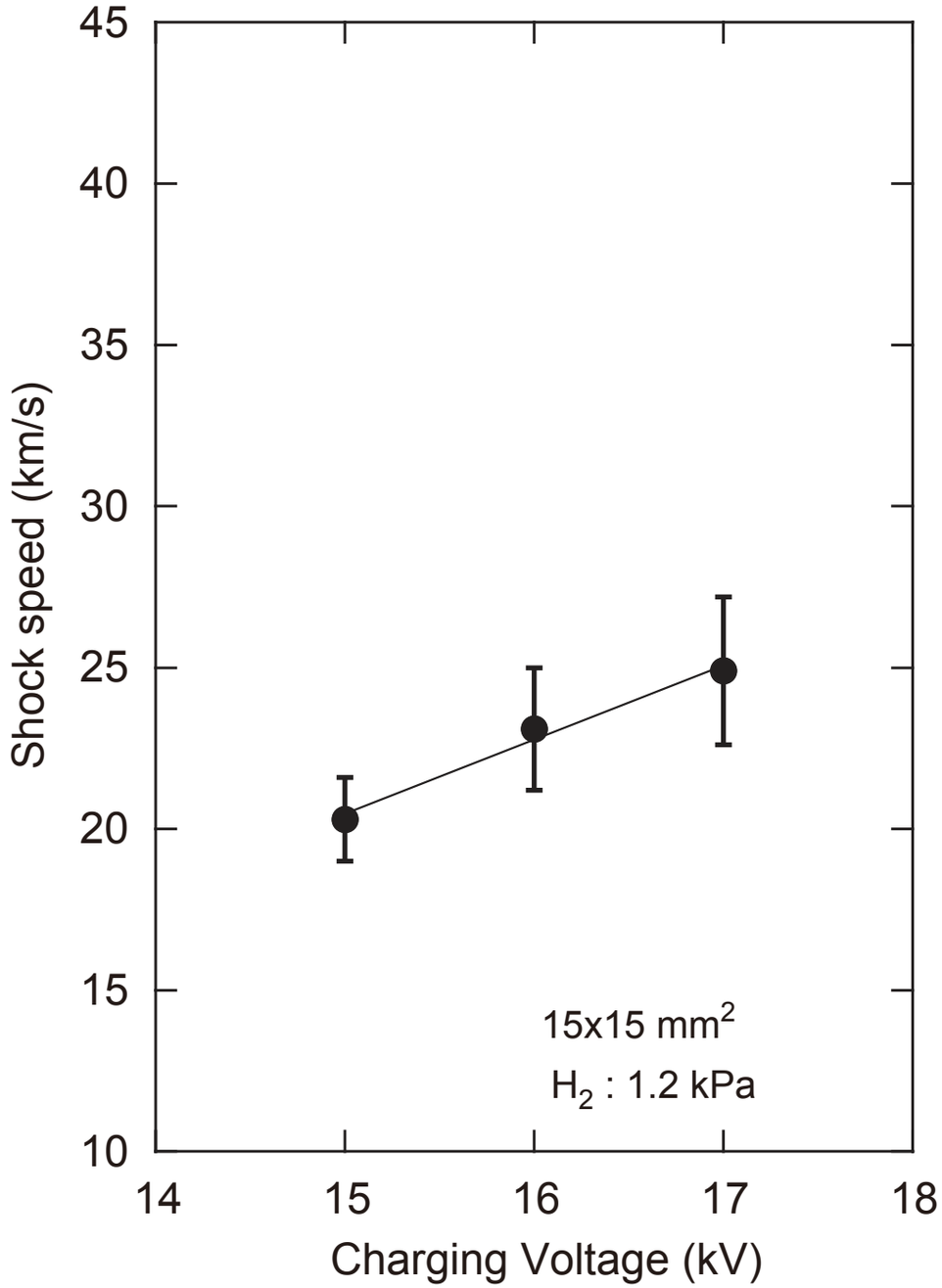
A typical streak image of shock-heated hydrogen gas*

*J. Hasegawa, et. al., Nucl. Instr. and Meth. A 606 205 (2009)

Shock Velocity for Shock Tube Structure



5 mm x 5 mm



15 mm x 15 mm

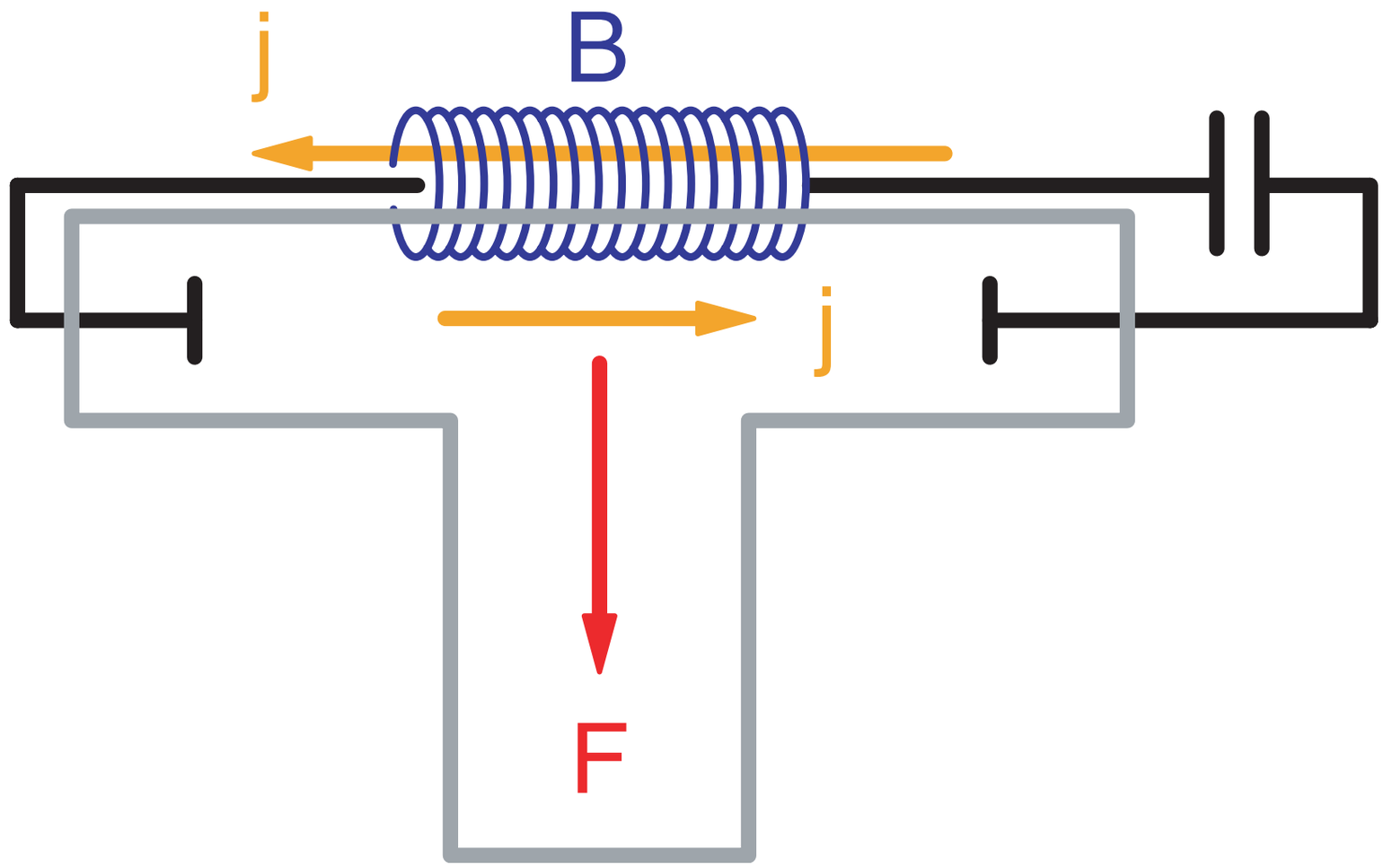
*J. Hasegawa, et. al., Nucl. Instr. and Meth. A 606 205 (2009)

How much the initial pressure do we need?

Since the energy resolution of a silicon detector (Passivated Implanted Planar Silicon) to measure ion energy is ~ 100 keV, nl (n: hydrogen atom number density, l: target thickness) should be 10^{18} /cc.

To consider l is ~ 1cm in this experiment, we need initial pressure of 1000 Pa.

Electro-magnetically Driven Shock Tube



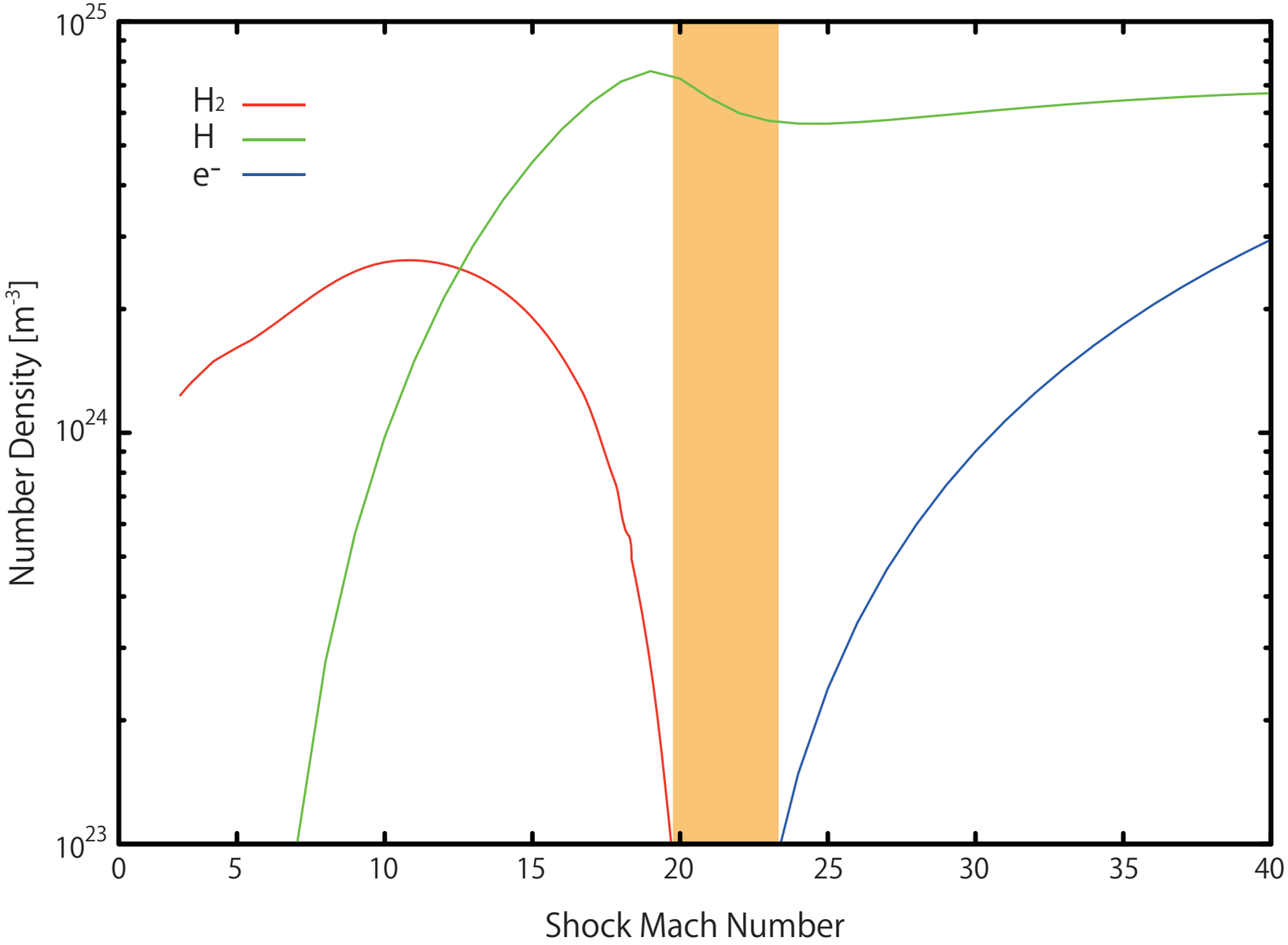
EM shock tube* can accelerate the target gas by the magnetic pressure and generate well-defined the shock heated condition. The condition can be estimated by Rankine-Hugoniot Relation with EOS.

* Y. B. Zel'dovich, Y. P. Raizer, Phys. of Shock Waves and High-Temp Hydrodynamic Phenomena, Academic Press. NY, 1967

19th international Symposium on Heavy Ion Inertial FUsion (HIF2012) August 12-17, 2012 Berkeley, California, USA

Shock parameters for dissociation target

Initial pressure: 1300 Pa, Initial temperature: 300K



At M ~ 20 (Vs ~ 26 km/s),

T behind shock is 6600K and the compression ratio is 10.

Propagation distance

$$\Delta t = L \left(\frac{1}{v_p} - \frac{1}{v_s} \right)$$

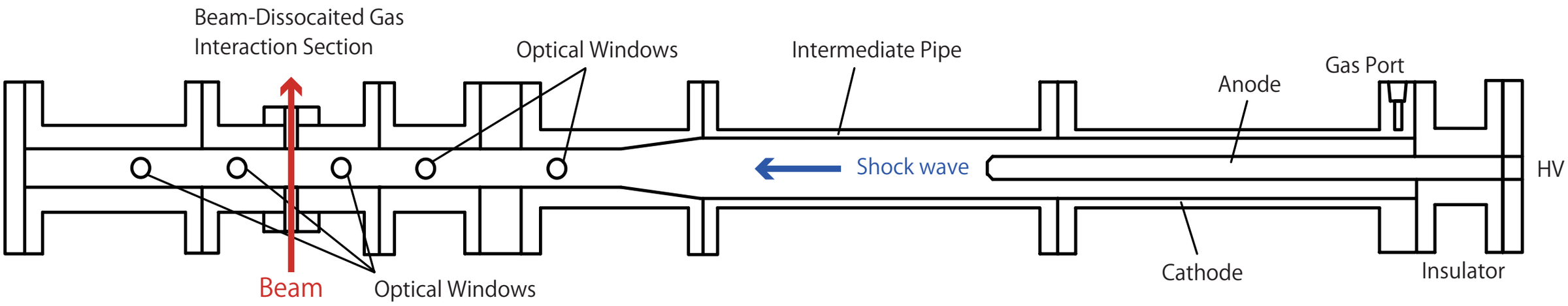
Previous Experimental Setup

L 72 mm
Shock velocity 26 km/s
Piston velocity 24 km/s
Δt ~200 ns

New Experimental Setup

L 620 mm
Shock velocity 26 km/s
Piston velocity 24 km/s
Δt ~1800 ns

New Electrodes for Dissociation Gas w Long Duration



To ensure the shock condition with long duration, we should measure the shock velocity in the wide region along the shock tube.

The intermediate pipe can be removed to investigate shock condition for the propagation distance.

19th international Symposium on Heavy Ion Inertial FUsion (HIF2012) August 12-17, 2012 Berkeley, California, USA

Summary

- The dissociation effect can be measured using hydrogen target for heavy ion beams.
- The electro-magnetically driven shock wave generates a well-defined dissociated gas target.
- To the shock wave condition with longer duration, we propose the new setup including the new electrodes.
- This new setup realizes us to measure the stopping power difference due to the dissociation effect for the warm dense matter experiment and heavy ion fusion sciences.